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THESIS

PRIORITIZATION OF CAPITAL PROJECTS

by

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PRIORITIZATION OF CAPITAL PROJECTS

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Public works capital projects in the U.S. naval forces are not prioritized and funded in a way that best uses limited operations resources and maintenance dollars. This thesis develops a linear model for public works commands to effectively prioritize and fund capital projects. This model allows each command to set its own criteria and weightings which are then used to score and rank capital projects. Using objective criteria, it seamlessly integrates new projects with existing projects into a command's Integrated Project List. The time formerly needed to manually rank each new project against all other projects is saved. Moreover, a command is able to keep a complete and comprehensive list of all unfunded capital projects. The subjectivity inherent in manual project priority decisions is removed. Ways to use existing computer systems in public works commands through Annual Inspection Summary reports are explored. The project decision process was studied through interviews conducted in commands at varying levels of the public works hierarchy. The linear model for project prioritization was developed in Excel. A spreadsheet sample of the linear model and detailed step-by-step instructions for its construction are available upon request from the author. Suggestions are made for further development of the project prioritization process.

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TABLE OF CONTENTS

LIST OF TABLES

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I. INTRODUCTION

A. THE PROBLEM

In the FY03 Presidential budget for the Navy forwarded to Congress, the budget line for maintenance and repair of real property is $1.478 billion. These funds are used to support 82 CONUS and 23 overseas installations. This is a little over 1% of the Navy's total budget. This money is used by public works officers (PWO) at installations to develop and fund capital projects. However, projects are not being prioritized and funded in a manner that best utilize the Navy's limited resources.

Projects are not evaluated using objective or weighted decision criteria that can score and rank projects against other projects within the base's Integrated Priority List (IPL). Projects are prioritized and funded during weekly management meetings where biased and subjective decisions criteria are used, which are based on personal experience, gut feeling, ranking officer influence or compromise. Quantifiable decision criteria are not used to manage unfunded capital projects. Additionally, PWO's keep and track between 10 to 20 percent of the base's total project backlog found in MAXIMO[1]. Therefore, 80 percent of base projects are either ignored or forgotten while they accumulate in MAXIMO. Furthermore, PWO's are not using the Annual Inspection Summary (AIS); which provides the most detailed information on the bases facility condition, to develop and fund projects. Finally, it is too difficult and time consuming for people to manage, track, and prioritize the entire base's capital projects, especially when the base IPL is relatively large or constantly in flux. This is particularly true at Navy regions, where a single regional office now manages what many individual bases used to do.

B. PROPOSED SOLUTION

This thesis developed a linear model to be used by public works commands. It uses command-weighted criteria to score and prioritize all capital projects to quickly

[1] MAXIMO is the NAVFAC public works database that tracks and stores work type, costs, manpower, equipment, material, dates and trades for each job. MAXIMO is copyrighted software of MRO Software.

integrate new with existing projects into a consolidated Integrated Priority List (IPL) for the base. Once a project has been scored and input into the model; the linear model prioritizes that project against all projects, ranking them from highest to lowest score. The model also gives the base a consolidated list of "to fund" projects, which is dependent on the commands current resource levels. The linear model also allows the command to assign constraint parameters for each Project Type so the base may differentiate different types of projects in order to set minimum execution levels for that type of project. The model is easily adaptive to different command constraint parameters or varying funding levels.

This thesis also gives examples of how Naval Facility Engineering Command (NAVFAC) computer systems can be used to help public works commands target and develop more projects based on the Annual Inspection Summary report. Additionally, by assigning the AIS as one of the command criteria in the linear model and giving it a higher weighted score relative to other command criteria, the linear model will target more AIS projects for execution. This will increase the total number of AIS projects funded by a base.

C. OUTCOME IF RECOMMENDATIONS NOT FOLLOWED

Installations will continue to fund and prioritize capital projects using subjective decision making criteria that do not give the Navy the best use of its limited resources. The maintenance and repair backlog will continue to grow while the base infrastructure deteriorates due to the lack of projects that are developed and funded by AIS information. Resources will therefore be wasted on projects that do not target the most critical areas.

Public works officers will continue to spend too much time in staff meetings discussing when their project ought to be funded or where to place it among the other IPL projects. Most projects will eventually get lost within MAXIMO, many of which would be the best projects to correct the base infrastructure problems. However, since these types of projects are typically low visibility, they will never be funded unless objective, quantifiable and measurable information shows their importance to the base.

II. BACKGROUND

A. PROPERTY TYPES AND RESPONSIBILITY

OPNAVIST 11010.20F (1996) defines real property as land (type 1 property) and improvements to land (type 2 property). A real property facility is a separate and individual building, structure or other real property improvement.

The maintenance of real property is a command responsibility (OPNAVIST 11010.23E, 1987). This responsibility is delegated to a public works officer (PWO) working for the commanding officer in charge of the region, installation or command.

The PWO's responsibilities include planning and executing military construction (MILCON) projects, developing and prioritizing repair and maintenance projects, along with budgeting and allocating resources to perform day-to-day repair and maintenance. Additionally, the PWO acts as a project manager and must resolve budget and construction issues during both the planning and execution phases. He or she also acts as the commanding officer's resident expert for facilities and provides advice to the commanding officer on such issues.

B. INTEGRATED PRIORITY LIST

Each command develops and maintains an Integrated Priority List (IPL). The IPL is a list of unfunded real property projects, called Specific projects. The IPL is used to finance projects from as funds become available throughout the year. Specific projects are commanding officer (CO) authority projects costing less than $750,000 to execute but are large enough to require planning and estimating. Projects exceeding $750,000 for construction or repair require Congressional MILCON authority and funding or major claimant approval respectively (OPNAVINST 11010.20F). The funding levels were increased from $500,000 to $750,000 in 2002 according to Base A's planning director (2002). Projects requiring more than 80 hours to execute require planning and estimating. Exceptions to this exist for larger projects that are routine in nature or for smaller projects that are complex.

C. PROJECT INITIATION

Projects are brought to the attention of the PWO's in different ways. For example, a facility tenant may contact the public works office to discuss a particular project that interests them, such a noisy or inefficient air conditioning system. The CO may show interest in a facility for one reason or another and request that public works develop a project. Public works or facilities staff members may notice an issue or problem while visiting a facility during routine business or by the formal inspection process known as the Annual Inspection Summary (AIS)[2]. Depending on the scope of the project, a public works planner and estimator (P&E's)[3] or construction contractor will develop a detailed cost estimate for each project that is submitted into MAXIMO and a job plan that lists out the jobs materials, scheduling requirements, and construction trades that are needed once the project is funded.

Projects are entered into MAXIMO when a request for a cost estimate is submitted by a customer. Since the Navy will realistically never receive enough resources to fund all valid projects, projects accumulate over time within the MAXIMO database. Since the person or customer that initiates a project often moves, projects that are not funded early, will likely be forgotten. According to all three commands interviewed, this problem can be compounded if an IPL is not formally maintained and projects are not objectively scored and reevaluated continuously as new projects are submitted.

During my tour as one of the Assistant Public Works Officers (APWO's) at Navy Region Hawaii, we were tasked to find all the projects within MAXIMO for our command. We were able to identify 430 projects. Of the 430 projects, our team only knew the history and background of 80. Over the course of six months, we researched as many projects as possible to determine how many of the remaining 350 projects were still feasible. We tried to the best of our ability to prioritize the 350 unknown projects within

[2] Facilities are not necessarily inspected annually as the name implies. For example, Base A inspects each facility on a three-year cycle. Base B inspects critical facilities annually; all others are inspected every five years.

[3] Planners and Estimators gather project information from the customer and develop a detailed project plan including construction trades, hours needed, materials, equipment and costs to complete the project.

the IPL. We ended up with a list of 400 projects; however, we were only able to rank the top 125 projects because we did not have enough history or decision criteria for the remaining projects to make an objective assessment. Since we did not have a process that could help us quickly prioritize the many different project criteria according to our newly developed criteria rating system, the prioritization process was long and cumbersome. After months of research, most of the projects remained un-prioritized and will likely never be funded.

D. ANNUAL INSPECTION SUMMARY PROCESS

Public works inspectors inspect each facility to identify maintenance and repair deficiencies. The deficiencies are categorized according to: structural, roof, electrical, mechanical, paint, special, or other. Special deficiencies are intended for elevators, cranes, and boilers. Other deficiencies are the deficiencies not otherwise categorized.

Each deficiency is coded with a "1" or a "2". A deficiency code of "1" is considered a critical non-deferrable deficiency and is coded with an:

(E) catastrophic environmental

(M) loss of mission

(S) life or death safety

(Q) quality of life

Deferrable non-critical deficiencies are coded with a "2" and a (D) – deferrable. Each deficiency is scored between 0-100. Scores between 70-100 are considered critical with 100 being the most severe deficiency.

An annual inspection summary report (AIS report) is generated each year and is forwarded to the public works office. The report lists all inspected facilities by facility number with the consolidated deficiencies listed under each facility. Line item repair costs are included for each deficiency to provide an estimate for the total installation facility repair[4] backlog. The estimates are general costs and are not used as an absolute repair cost. If a more detailed cost estimate is required, a facility project will be

[4] Backlog of Maintenance and Repair (BMAR) is a consolidated backlog list of all the "critical" deficiencies identified in the AIS report. The BMAR is a tool to help in developing the POM for the FYDP. (OPNAVINST 11010.23E).

developed to address the AIS deficiency items. For the detailed AIS process, refer to OPNAVINST 11010.34B (1987).

According to the above instruction, the AIS should lead to the development of realistic long-term objectives and resource allocation at all levels of the command. However, during my experience as an APWO, the AIS report was seldom used as a tool for developing CO authority (Specific) projects. The AIS report and maintenance backlog is used more to generate the POM in the FYDP than it is used to generate facilities projects (Head Supervisor of the Maintenance Division of Base B, 2002).

The AIS process is a slightly different process at a Public Works Department than at a Public Works Center (PWD vs. PWC). At a PWD the AIS is a continuous process throughout the year, at a PWC, the AIS is a single yearly product.

A PWD is generally a smaller organization with fewer resources and workers compared to that of a typical PWC. The PWD works directly for the installation and receives annual appropriated funds to do facility projects. The PWO and staff not only manage the work execution branch for the customers and installation, but also must budget, plan, and fund base projects throughout the year to include maintaining the installation IPL.

The PWD funds its own inspectors to generate the AIS report for the management staff. Because the AIS information is gathered by and used for the PWD, when a notable repair or maintenance item is identified, the PWD can develop a project or call in an Emergency, Service, or Minor[5] to address the AIS issue depending on the size and scope.

In contrast, a PWC is a Navy Working Capital Fund activity which receives all of its funding by selling products and services to its customers. It receives no appropriations from the installation. The PWC is one of many work execution vehicles the installation or region[6] PWO uses to execute work; others include contractors,

[5] Emergency - an immediate repair to address a problem to safeguard life, property, or mission. Service – routine repair or maintenance taking less than 16 hours to complete Minor – routine repair or maintenance taking between 16 and 80 hours to complete.

[6] In FY1999, large fleet concentrated areas began consolidating from individual commands and bases into larger navy regions. Essentially, similar base functions like comptrollers, facilities, and police, were rolled into large regional equivalents.

Seabees, and self-help. The IPL is developed and maintained by the installation PWO, not the PWC. A PWD is both a work executor and a project decision maker for an installation.

PWC's are located in fleet concentration areas; therefore, facilities offices located near PWC's do not have in-house staff to perform the AIS inspections. Instead, the PWO hires the PWC inspectors to inspect the installations facilities. The AIS report is generated annually by PWC and given to the facilities office.

PWC's perform work only when hired to do specific tasks by the customer, therefore; AIS inspectors will not submit work back to PWC during the AIS process. However, if an AIS inspector notices an extreme problem during the inspections, he will notify the facilities office so they can initiate the proper work request.

E. ANNUAL INSPECTION SUMMARY REPORT SHORTCOMINGS

The AIS report is not used as the primary IPL project generator. According to Tufts (2000), more facilities projects should be generated from the AIS report. Not only does it show that the OM&N repair and maintenance budget is under funded, but it also costs Navy Region Hawaii $250K per year to hire PWC to inspect the facilities we manage. This report shows, in detail, the condition of each of our facilities, and should be used to target repair money where it is most badly needed.

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III. METHODOLOGY

A. COMMANDS INTERVIEWED

Three public works commands were interviewed. They represent the Navy's public works system today including, a Public Works Center (PWC), Public Works Department (PWD) and a Navy Region Facilities command.

Although only three commands were interviewed in this thesis, the information is used to make general conclusions and recommendations for all Navy public works commands. The people that were interviewed have all been assigned to other public works organizations in the Navy and, therefore, the scope of the collected information extends beyond three commands.

The point of this thesis is not to suggest that a particular public works command is doing anything wrong or inappropriate, but rather to provide a better way to manage project decision-making and funding constraints. However, in order to alleviate the concerns of the people I interviewed and gain open communication, I have left the interviewees and command information anonymous.

B. LITERATURE REVIEW

In order to gain broad guidance in facility management, facility responsibility, AIS inspection and processes criteria, Investment Categories (IC's), project classifications and funding limits, I reviewed the following instructions and manuals:

OPNAV Instruction 11010.20F, released June 1996

OPNAV Instruction 11010.23E, released May 1987

OPNAV Instruction 11010.34B, released February 1987

NAVFAC MO-322 Volume 1, released March 1993

NAVFAC MO-321, released September 1985

Specifically, Investment Category (IC) information was gained from OPNAV Instruction 11010.23E, which is shown in Table 5.3. The IC's were used to development one of the decision variables shown in the linear program model that is discussed in Chapter IV. Eighteen IC's are broken down into "groupings of similar facilities with

related contribution to the Navy missions, such as aviation operational, waterfront operational, and utilities

C. INTERVIEW QUESTIONS

I interviewed three public works commands and one public works center information system department.

Interviews included:

- One (1) Navy Region Facilities Dept.
- One (1) Public Works Departments
- One (1) Public Works Center
- One (1) Public Works Center Information System Dept.

Questions asked during the public works interviews:

1. Does your command use the AIS to generate jobs?
2. In your educated guess, what percentages of your funded projects are derived specifically from the AIS report?
3. Do the Planners and Estimators use the AIS when developing “Specific” Projects?
4. What is your AIS inspection cycle, once a year, every two years, etc.?
5. Do you have any formal criteria that you use to prioritize projects?
6. Does the AIS database get updated when projects or service calls repair AIS deficiencies?
7. Would you like MAXIMO or other NAVFAC computer system to recommend projects to you based on the AIS data?
8. Do you use any formal linear or similar model to help your command prioritize projects?
9. Do you consider Investment Categories (IC’s) as a decision variable for your projects?
10. Would you use or like to use a program that would help you prioritize projects based on your command criteria and weighting?
11. How many projects does your command have active in the MAXIMO database?

12. How many do you actually track?
13. What process do you use to prioritize projects at your command?
14. Do you know of any base or command that uses a linear model to help prioritize "Specific" projects?

Questions asked during the PWC information system engineer interview.

1. How difficult would it be to use MAXIMO or other command computer system to help identify projects based on Critical AIS criteria?
2. In your best estimate, how much would it cost each base to implement such a system?
3. Would it be more difficult to get the resources needed to do such a project at a PW Department vs. a PW Center?
4. How do you think this might be done?
5. Do you have any ideas?
6. Would a system be able to track the AIS maintenance backlog over time to see if improvements are being made to reduce the AIS backlog, especially the critical AIS backlog?

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IV. LINEAR MODEL METHODOLOGY

A. OVERVIEW

The linear model that was created for this thesis should be used as a guide for other public works organizations to help develop their own linear model. The criteria and applied weighted percentages, found in Table 4.1, will be unique to each public works command.

Since the linear model provided in Appendix A is Base B specific, Appendix B is provided to give general instructions and examples to help another commands develop an Excel linear model.

B. LINEAR PROGRAM MODEL CRITERIA

Base A (regional facilities) and Base B (PWD) were used to develop the linear program model criteria. Base C (PWC) had no written or specified criteria; therefore it was not considered during the development of the linear model's criteria. Additionally, since no base identified Investment Categories (IC's) as project criteria, I added the IC's to the linear model decision variable criteria as outlined in OPNAV Instruction 11010.23E. A total of twelve decision variables are identified in Table 4.1.

#	Criteria	Base A Weighting	Final Model Weight Based on Base B Input
1	Safety	25%	17%
2	Mission	20%	16%
3	Critical AIS	15%	14%
4	Quality of Service	None	13%
5	Life Cycle Cost Savings	8%	10%
6	Urban Renewal	10%	8%
7	CO Priority	5%	7%
8	Footprint Reduction	12%	5%
9	AIS	3%	4%
10	Project Cost	2%	3%
11	Code Upgrades	None	3%
12	Investment Category	None	None

Table 4.1. Linear Model Criteria and Weightings.

I asked Base A's assistant public works officer and Base B's Head Supervisor of the Maintenance Division to provide me with their respective weighting for each criterion, which is shown in Table 4.1. I asked Base B to use Base A's criteria since Base B does not use their published criteria for project prioritization.

After taking Base A's input and weighting, Base B had the opportunity to change and modify the categories. Base B's Head Supervisor of the Maintenance Division wanted to increase CO Authority, Footprint Reduction, and Life Cycle Cost Savings. Also, he wanted to incorporate both Code Upgrades and Quality of Service criteria into their decision variables. He pointed out that one of the CNO's top five priorities was Quality of Service and felt this should be a relatively high category.

Through discussion with Base B's Head Supervisor Maintenance Department, the final linear program model criteria were established shown in the right-hand column of Table 4.1. However, this linear program model is only an example based on Base B's input. Since the model is being tested using Base B's top 43 Specific unfunded projects, the model uses Base B's criteria and weighting.

C. DEVELOP THE LINEAR MODEL

Step 1: First, existing command criterion was collected from both Base A and B. The criteria was either currently being used or it was suggested that they should be used for the model.

Step 2: Once the criteria were set, Base B prioritized it from most important to the least important. Weighted percentages were applied after the importance order was established. The criteria were ranked in descending order with the highest applied percentage criterion, being the most important, to the lowest assigned percentage, being the least important. Although it is not essential that the sum of the percentages added up to 100 percent, it is recommended for record keeping purposes in order to judge how well any given project scores relative to the absolute highest or lowest score possible.

For example: Suppose a command uses the following five criteria, the sum of the criteria weighting should equal 100 percent.

Criteria	Percent Ranking
Safety	35%
CO Priority	20%
Critical AIS	18%
AIS Regular	15%
Footprint Reduction	12%
Sum	**100%**

Step 3: A bonus of up to five percent was added to the model, which is dependent on the Specific projects Investment Category Code shown in Table 4.2. All three public works commands that were interviewed did not use Investment Categories as a criterion they consider when funding or prioritizing Specific projects. However, according to OPNAV Instruction 11010.23E (1987), bases should reduce maintenance backlogs "prioritized by Investment Category". Bonus percentages were assigned according to the Investment Category importance level found in Table 5.3. High priority Investment Category's are assigned a five percent bonus, medium priority Investment Category's are assigned a two and one half percent bonus, and low priority Investment Category's are not assigned any bonus as shown in Table 4.2.

Investment Category's	Bonus Percentages
Administration Facilities	1.000
Ammo Supply and Storage Facilities	1.025
Aviation Maintenance Production Facilities	1.025
Aviation Operational Facilities	1.050
Communication Operational Facilities	1.000
Medical Facilities	1.025
Other Maintenance Production Facilities	1.000
Other Operational Facilities	1.000
Other Personnel Support Facilities	1.025
Other Supply and Storage	1.000
POL Supply and Storage Facilities	1.025
RDT&E Facilities	1.000
Real Estate and Ground Structures	1.000
Shipyard Maintenance Production Facilities	1.025
Training Facilities	1.050
Troop Housing and Messing Facilities	1.050
Utilities	1.050
Waterfront Operational Facilities	1.050

Table 4.2. Investment Category Bonus'.

Step 4: Cost was considered an independent criterion in this linear model (i.e. a higher costing project scores lower in this linear model than a lower cost project with all else being equal). The linear model scores cost according to Table 4.3. This should be updated periodically to account for inflation.

Cost	Score
$1 - $9,999	10
$10,000 - $24,999	9
$25,000 - $49,999	8
$50,000 - $99,999	7
$100,000 - $149,999	6
$150,000 - $199,999	5
$200,000 - $249,999	4
$250,000 - $399,999	3
$400,000 - $1,999,999	2
$2,000,000 +	1

Table 4.3. Cost Criteria Score.

Step 5: Constraint parameters can be set for each Project Type. Project Types are found in Table 4.4. Base A had pre-established Project Types and therefore Base A's were used for this model. Project Types are ways to differentiate how the command classifies its projects according to scope. Project types are different from criteria. Each project is assigned to one or more Project Type(s), and then each project is scored according to the criteria set up in the model. For example: The Project Type could be "Paving" (the road on Elm street). The criteria found in Table 4.1 were used to score each project.

Constraint levels can be set up against each Project Type, which allows the command to set a minimum projects level within a Project Type regardless of how well the project scored based on the command criteria. For example, suppose that the command wants to paint at least three buildings each year. After scoring all possible projects, the painting projects score relatively low using the models criteria compared to all other projects. However, if the command sets the "Painting" parameter at a minimum

of three, the linear model, regardless of score, will recommend for approval at least three painting projects based on a constraint level set**.**

Project Types
Electrical
Mechanical
Structural
Roofing
Painting
Paving
Piers/Wharfs
Renovation
Urban Renewal
Footprint Reduction
Seabee

Table 4.4. Project Types.

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V. FINDINGS AND RESULTS

A. HOW BASES PRIORITIZE PROJECTS

Specific projects are placed on the IPL depending on how well the project scores on command criteria. Each command uses their own unique criteria for ranking IPL projects. For example, according to the assistant public works officer at Base A, they evaluate each new project using the nine defined criteria listed in Table 5.1 to help them place their projects within their existing IPL. However, according to the Head Supervisor Maintenance Division at Base B (2002) and the Program Manager at Base C (2002), a project management board (PMB) meets weekly to discuss new projects and funding issues but does not use published criteria to help them place or score new projects within their IPL. According to the Head Supervisor of the Maintenance Department at Base B, when funding becomes available, the PMB uses personal experience, discussion, and CO interest to decide which of their IPL projects will be funded. Although Bases A and B have published IPL criteria, which are listed in Table 5.1, only Base A routinely uses their criteria to prioritize projects. Base C has no published command criteria.

Priority	Base A Criteria	Base B Criteria
1	Safety	Routing
2	Mission	Preventative
3	Critical AIS	Functional
4	Footprint Reduction	Safety/Security
5	Urban Renewal	NAVOSH (RAC 4 or 5)
6	Life Cycle Cost Savings	NAVOSH (RAC 2 or 3)
7	CO Priority	Command Interest
8	Deferrable AIS	Life/Property Threat (RAC 1)
9	Project Cost	

Table 5.1. Base Published Decision Criteria.

B. SHORTCOMING OF THE IPL PROCESS

Naval Facilities Engineering Command (NAVFAC); the Navy's engineering and construction expert, provides broad guidance for facilities management in publication

MO-321 (1985), Facilities Management. According to Jones (1985), "great latitude is permitted in the execution of facilities management responsibilities".

Installations exercise this latitude by developing their own IPL criteria. However, according to this research, installations are not using or are ineffectively using objective criteria to fund projects from their IPL. The Head Supervisor of the Maintenance Division at Base B (2002) doubts if any Navy base is using an objective model to fund their Specific projects, "I'll bet there is no command currently using a linear or other model to prioritize facility projects. They probably all do it similarly to what we do."

All bases interviewed have management meetings to discuss their capital projects. These meetings takes time and resources trying to place new projects within the IPL, "it can be a long and tedious process to individually place each new project into the IPL, especially when we have many new projects that week. Anyway, how do you place one project ahead of the other within the same category? We have to guess." (Project Manager Base A, 2002).

According to the assistant public works officer at Base A, they are only able to evaluate one criterion at a time rather than being able to simultaneously evaluate all nine. This increases the time it takes to maintain the IPL while at the same time decreases the objectivity in assigning projects within the IPL. For example, the management team takes all the projects with Safety issues first and ranks them sequentially from most severe to least. Then the team takes the remaining projects that have mission impact and orders them sequentially. They continue this process until all projects have been placed in order. They then go back to bring up some projects from lower criterion and try to objectively place the highest ranking lower criterion projects into the mid and lower ranking higher criterion projects; see prioritization process.

C. PRIORITIZATION PROCESS

Step #1: Mark each project with all the criteria that apply.

Project	Safety	Mission	Critical AIS	CO Priority
Project A	X		X	
Project B		X		
Project C				X
Project D	X			
Project E			X	X
Project F		X		
Project G	X			X
Project H	X	X		
Project I			X	
Project J	X			
Project K		X		X
Project L			X	
Project M	X	X		X
Project N		X	X	
Project O	X		X	

Most Important to Least Important Criteria

Table 5.2a. Criteria Assignments.

Step 2: Prioritize the Projects within each criterion from most important to the least important. The most important criteria are ranked first. The least important criterion is ranked last. Thereby, when a project has more than one criterion, the most important criterion will be the ranking one shown in Table 5.2b. For example, if a project falls under both Safety and Mission, Safety will be the ranking criteria.

Rank	Safety	Mission	Critical AIS	CO Priority
1	Project O			
2	Project A			
3	Project H			
4	Project M			
5	Project J			
6	Project G			
7	Project D			
8		Project F		
9		Project N		
10		Project B		
11		Project K		
12			Project E	
13			Project L	
14			Project I	
15				Project C

Table 5.2b. Criteria Prioritization.

Step 3: Finally, lower criterion projects are checked against higher criterion projects and moved up the list. For example, project F (Mission) is checked against project D (Safety), if it is more important overall, it will be move up the list. Project F will continue up the list until it fails to rank higher in the list. This is shown in Table 5.2c.

Rank	Safety	Mission	Critical AIS	CO Priority
1	Project O			
2	Project A			
3	Project H			
4	Project M			
5		Project F		
6	Project J			
7	Project G			
8		Project N		
9	Project D			
10		Project B		
11			Project E	
12		Project K		
13			Project L	
14			Project I	
15				Project C

Table 5.2c. Final Priority.

Although the team tries to be as objective as possible, there is no weighted score to show were each project ought to be placed within the various criteria levels. As such, the objectivity of the process is diminished. "It is like throwing darts against a wall", (Program Manager at Base A, 2002).

Base B uses a more subjective process. The Head Supervisor of the Maintenance Division (2002) stated that the management board discusses high interest projects during the PMB meeting and comes to consensus as to which projects to fund, in order, as funding become available. No formal ranking process or criteria are used to prioritize projects. Projects that do not have a strong champion do not usually get funded.

Within the MAXIMO computer system as of 1 September 2002, Base B had 436 Specific projects that were active. Most of the 436 projects are not tracked by anyone at the PWD and will likely remain in the system indefinitely unless they become high interest either by a project champion taking interest or the project gains visibility caused by continuous routine service calls to address facility deterioration.

D. ANNUAL INSPECTION SUMMARY FINDINGS

According to the Project Manager at Base A and the Head Supervisor of the Maintenance Division at Base B (2002), most installations in their experience have used the AIS report more as a Program Objective Memorandum-Future Year Defense Plan (POM-FYDP) tool than as a project-generating tool. The facilities repair and maintenance backlog that is shown in the installations AIS report is primarily used to justify increases in maintenance and repair dollars, not to actually fund specific repair items identified in the report. However, according to the public works officer at Base A he is trying to fund more projects based on the AIS report. His goal is to fund over 80 percent of all their projects from the AIS report. However, the planning director at Base A stated that the majority of their projects still are not developed from the AIS report.

A newly generated AIS report becomes outdated and inaccurate a few months after it is forwarded to the PWO. Since most CO authority projects are generated from sources other than the AIS report, and Emergency, Service, and Minor repair work is continuously being performed on the facilities all the time, the AIS information according to the planning director at Base A (2002) is often inaccurate and does not reflex real-time outstanding maintenance items that have since been corrected by other projects and service calls. This problem is increasingly compounded the longer the AIS inspection interval exists between each facility inspection. A facility that is inspected annually has more accurate AIS facility information than one that is inspected on a three or five year interval.

E. MAXIMO PROJECT BACKLOG

Maintenance and repair project backlogs ranged from 400-500 in MAXIMO at all three bases that I interviewed. However, no base used all the projects in MAXIMO as their bases IPL, but rather, each base kept separate IPL's using an Excel spreadsheet. Their IPL's took only select projects from MAXIMO; they only tracked and funded those projects. The remaining projects in MAXIMO will likely not be funded and continue to accumulate over time according to the Head Supervisor of the Maintenance Division at Base B (2002).

F. INVESTMENT CATEGORY'S

According to OPNAV Instruction 11010.23E (1987), capital repair and maintenance projects should be prioritized and funded using the facilities Investment Category, "…in order to maximize available funding, the critical backlog will be reduced in a priority sequence as follows". Table 5.3 shows the investment categories with their respective priorities. The investment categories provide guidance as to where to allocate resources in order to maximize "its effect on operational readiness."

	Investment Category	Priority		
		High	Medium	Low
1	Aviation Operational Facilities	X		
2	Communication Operational Facilities			X
3	Waterfront Operational Facilities	X		
4	Other Operational Facilities			X
5	Training Facilities	X		
6	Aviation Maintenance Production Facilities		X	
7	Shipyard Maintenance Production Facilities		X	
8	Other Maintenance Production Facilities			X
9	RDT&E Facilities			X
10	POL Supply and Storage Facilities		X	
11	Ammo Supply and Storage Facilities		X	
12	Other Supply and Storage			X
13	Medical Facilities		X	
14	Administration Facilities			X
15	Troop Housing and Messing Facilities	X		
16	Other Personnel Support Facilities		X	
17	Utilities	X		
18	Real Estate and Ground Structures			X

Table 5.3. Investment Categories.
From: OPNAV Instruction 11010.23E

G. PROJECT MATRIX

Guidance for the linear decision-making model is found in NAVFAC MO-321. Table 5.4 outlines a possible decision criteria process that a base or command could use

to prioritize projects. “Priority assignments are essential in determining the importance of each job in relation to the other…the use of a priority classification system will assist in optimum resource utilization.” However, according to Base B (2002), the matrix shown in MO-321 is too simplistic for their project prioritization process. Additionally “it would be extremely difficult to keep track and prioritize hundreds of projects at once without the use of some sort of database to track our projects for us”.

Emergency or Exceptional Items Receive a 1		Work Classification			
		Safety	Functional	Preventative	Appearance
Importance Level	High	2	3	4	6
	Routine	3	5	7	8
	Low	6	7	9	10

Table 5.4. Sample Priority Matrix.
From: NAVFAC MO-321

This “Sample Priority Matrix” was used in concept to develop the linear program model for this thesis, which is found in Appendix A.

H. RESULTS OF THE PW INTERVIEW QUESTIONS

Italicized question are subsequent questions that came up during the interview following the response to the primary question.

1. Does your command use the AIS to generate jobs?

All three commands said they used the AIS to help them generate some of their jobs. However, only one of the three commands expressed that their goal was to use the AIS as the primary means of funding projects. All three bases admitted that most of their projects are generated from sources other then the AIS but could not identify a specific number.

1a. *I asked why the command wanted to generate and fund most of their Specific projects from the AIS.*

The command informed me that their bases infrastructure is getting very old, and if they continue to ignore or downplay the AIS as they have in the past, their infrastructure would continue to deteriorate. They told me their base is getting so bad; it is having trouble operating in some of their facilities. Further, they admitted that three roofs had collapsed within the last year on the base.

1b. *I asked if AIS had shown problems with the roofing systems that collapsed prior to the collapse.*

He said he didn't know for sure but believed that AIS probably had the roofs condition in it.

2. In your educated guess, what percentages of your funded projects are derived specifically from the AIS report?

All bases said that most of their current projects were generated from other sources. The highest of the three said that about 35-40% were generated from the AIS; the lowest said that less than 20%. No base had a means of actually measuring how many of their projects are actually funded from the AIS.

3. Do the Planners and Estimators use the AIS when developing "Specific Projects?

The PWD said their P&E's look at the AIS report when they develop Specific projects for their facilities. Neither the regional facilities command nor the PWC said the P&E's check the AIS when developing a Specific project.

4. What is your AIS inspection cycle, once a year, every two years, etc.?

The time between AIS inspections varied from one year to five years for each facility. Both the PWC and regional facilities command inspected their facilities one a three-year cycle. The PWD inspected some facilities annually and others every five years, depending on the criticality of the facility.

5. **Do you have any formal criteria that you use to prioritize projects?**

The regional facilities command has nine criteria they routinely use when prioritizing projects. The PWD has eight criteria but admits they don't use them. The PWC said they did not use any nor had any published.

6. **Does the AIS database get updated when projects or service calls repair AIS deficiencies?**

Currently, no base updates the AIS data when service work is done on their facilities that may correct AIS line items. The PWD said they do update the AIS database when Specific projects are accomplished. However, they admitted that it is not done 100% of the time. Neither the regional facilities command nor the PWC currently update their AIS database as work is accomplished. However, the PWC is developing a GIS system that will update by adding and removing AIS line items as work is accomplished in their facilities. The PWC said when the system is up and running, the base will track, monitor and update AIS line items routinely. The regional facilities command said they currently have no means of updating the AIS information in real time; however, if the local PWC provided them with the means of being able to update and track AIS information, either in MAXIMO or a GIS system, they would commit to that goal.

7. **Would you like MAXIMO or other NAVFAC computer system to recommend projects to you based on the AIS data?**

All three bases said they would like MAXIMO or their GIS system to recommend projects to them based on AIS data. All admitted they were not sure how such a system might work.

8. **Do you use any formal linear program to help your command prioritize projects?**

None of the three commands used a linear model or any computer system to help prioritize their Specific projects. All three expressed interest in the thesis model. However, only one base said they would likely use the linear model in the current form.

8a. *I asked why they thought they would not use a linear model similar to the one developed in this thesis from the two commands who thought they would probably not.*

All three said they currently use MAXIMO as a work input database. However, all three commands said their commands kept a separate spreadsheet of their "to fund" projects. All three bases said their "to fund" project spreadsheet was a much smaller list of projects that they tracked and fund off throughout the year. One base tracked as many as 120 "to fund" projects in their spreadsheet at any time while another had as little as 35 projects. The other base tracked anywhere from 40 - 60 projects.

The two bases expressed concerns about having to keep and maintain another spreadsheet or incorporating their current "to fund" list into a linear model. One base said they had 436 projects currently in MAXIMO but only currently had 43 "to fund" projects. Another base said they have at least 500 projects in MAXIMO but tracked only a small percentage of those projects. One base didn't know exactly how many projects they currently had in MAXIMO but were sure it was in the multiple hundreds. When explained that this linear model was meant to track all MAXIMO projects and rank the projects in an Objective manner so they wouldn't have to keep a separate "to fund" spreadsheet, they were all concerned of having to keep track and manage such a large database.

8b. *I asked if they thought it would be a good tool if it were incorporated into MAXIMO as a tool.*

All three expressed varying levels of interest. Two bases showed relatively high interest in such a tool. One showed mild interest in such a tool.

8c. *I asked from the base that only showed mild interest why they weren't more positive about such a tool if it were in MAXIMO.*

They were concerned about the time it would take to have to rank each project against the criteria every time they input a new Specific project into MAXIMO.

9. **Do you consider Investment Categories (IC's) as a decision variable for your projects?**

None of the three commands prioritized projects or gave any considerations to the Investment Categories when prioritizing or funding projects.

10. **Would you use or like to use a program that would help you prioritize projects based on your command criteria and weighting?**

All three bases expressed the importance of being able to set the criteria and criteria weighting to a linear model for their command. All three bases expressed concerns of having NAVFAC or any other command standardize the criteria if such a linear model was ever adapted Navy wide.

11. **How many projects does your command have active in the MAXIMO database?**

Project numbers ranged from over 500 to multiple hundreds. Only one base had an exact number at the time of the interview; 436 projects in MAXIMO.

12. **How many do you actually track?**

All three bases said they tracked a subset of projects that existed in the MAXIMO database. The regional facilities had120 projects; the PWC had 35 projects, and the PWD had 43 projects on the date of the respective interviews.

13. **What process do you use to prioritize projects at your command?**

Regional facilities said they follow their own written prioritized criteria and try to fund projects according to that criterion. The PWC and PWD both said they rely on management meeting where they discussed high interest projects and funded them accordingly.

13a. *I asked what types of items you discuss at the management meetings to influence a projects ranking.*

A consolidated list follows:

CO Priority
Safety items
Persistent customers
Customer is high ranking or high influence

Upcoming inspections
System failures
Meetings with other Departments
Routine Maintenance Items
Location of the facility
Mission of the facility
Changes in circumstances
Environmental items
New commander
Multiple requests
AIS items
Politics

14. Do you know of any base or command that uses a linear model to help prioritize "Specific" projects?

None of the three bases that I interviewed used or knew of any base or command that uses a linear model to prioritize Specific projects.

I. PWC INFORMATION SYSTEM ENGINEER INTERVIEW

1. How difficult would it be to use MAXIMO or other computer system to help identify projects based on Critical AIS criteria?

The new GIS module we developed this year allows the user to click on a building from a GIS map, which pulls up a list of all the facilities AIS deficiencies, critical backlog and the total backlog dollar amount.

2. In your best estimate, how much would it cost each base to implement such a system?

He estimated the cost to develop this to be about $4000, however, his command already had a GIS system in place. He said as long as the command had a GIS system in place, it shouldn't cost much more than $4000 per installation.

2a. *I asked if the same information could be gathered using MAXIMO, since most of the smaller bases don't have the resources to fund their own GIS system but all have access to MAXIMO.*

He believed that it probably could be since it uses information already existing at each command; however, he wasn't sure how MAXIMO would be programmed since he did not work with MAXIMO.

3. Would it be more difficult to get the resources needed to do such a project at PW Department vs. a PW Center?

He informed me that two other PWC's are in collaboration with the PWC he works for and he knew of another PWC that is developing a similar system at a different location. However, since he didn't know of any PWD having the resources to fund their own GIS system, he admitted that at least for the time being, PWD would likely be limited to using MAXIMO.

4. How do you think this might be done?

Since all the information we use is routinely collected at most public works commands, it's just a matter of programming the computer system to use existing databases to pull custom reports that the command wants.

5. Do you have any ideas?

At our command, we are color-coding all our facilities in the GIS module so the user can quickly identify if a facility is above, average or below the backlog maintenance requirements with respect to other facilities. As an example, we take the BMAR (Backlog of Maintenance and Repair) and divide it by the PRV (property replacement value), BMAR / PRV. The GIS module compares this ratio with other facilities on the base and applies a color code to that facility depending on how well it scored relative to other facilities. In our model, green is good and red is bad with various shades of each representing the middle.

6. Would a system be able to track the AIS maintenance backlog over time to see if improvements are being made to reduce the AIS backlog, especially the critical AIS backlog?

Currently, this is not part of the module, but it wouldn't be that difficult to program. In my estimate, it wouldn't take more then a few thousand dollars per base.

J. LINEAR MODEL FINDINGS

Table 5.5 shows the results comparing the prioritized order of how Base B initially ranked their 43 Specific projects from highest to lowest vs. how the linear program ranked the same 43 projects using their criteria and criteria weightings.

Base B scored each project in the linear model according to the criterion of the model without knowing where they initially ranked that project. The following steps were taken to minimize the chance of influencing the criteria scoring process.

First, I asked the Head Supervisor of the Maintenance Division Base B to give me their 43 IPL projects ranked in order from highest to lowest.

Next, I scrambled the projects order and inserted the twelve criteria into the columns above the 43 projects, but I withheld the criteria weightings they agreed to earlier in order to minimize any attempts to manipulate the results to fit the data to produce results similar to their known prioritized order.

Next, I gave the sample back to Base B for him to fill in each cell according to how well he thought each project ranked against the twelve criteria using a scale from one to five; one being the lowest and five being the highest.

Next, he sent me back his inputted results for each project.

Finally, I ran the linear model using Base B's input.

Table 5.5 shows the results. Appendix A shows how Base B scored each of their projects.

Model's Priority	**Base B's Priority**	**Model's Priority Continued**	**Base B's Priority continued**
1	42	22	22
2	19	23	24
3	18	24	15
4	35	25	3
5	13	26	32
6	30	27	11
7	1	28	12
8	16	29	25
9	40	30	7
10	39	31	9
11	31	32	21
12	2	33	8
13	33	34	27
14	29	35	10
15	38	36	41
16	28	37	4
17	43	38	36
18	14	39	17
19	26	40	23
20	34	41	20
21	37		

Table 5.5. Linear Model's vs. Base B's Priority.

Columns 1 and 3 show the linear model's prioritization of Base B's projects. Columns 2 and 4 show Base B's initial project priority's in their IPL. Projects 5 and 6 from Base B's list are not included in Table 5.5 because they will be funded using another source of funding; therefore, only 41 actual projects exist in this table.

Differences exist between the linear models priorities and Base B's priorities. For instance, the linear models number one "to fund" project is Base B's forty-second "to fund" project. Although the differences may appear to be dramatic between the computer model and the bases priority levels, Base B's Head Supervisor of the Maintenance Division (2002) offers reasons why some projects are not funded earlier in their list. For example: he offers reasons like, weather and seasonal considerations, command coordination issues, project synchronization with other projects or events, projects under contract negotiations, project still in the design phase, project requires planning or a study is being conducted on the project to identify various options.

This linear model only evaluated projects that had already been identified as "to fund" projects, which accounted for only 43 of the 436 possible projects in Base B's MAXIMO database. This leaves 393 projects that have not been evaluated or scored, which leaves 90 percent of base B's projects not scored or evaluated.

I asked the Head Supervisor of the Maintenance Division at Base B (2002) if he thought if any of the remaining 393 projects in MAXIMO would likely score higher than the 43 projects they had identified in their "to fund" list. He told me that he was sure that many of the remaining MAXIMO projects would likely score higher than many of their existing "to fund" projects if they were scored using rated criteria. However, "since most of the MAXIMO projects simply are not known, we have no means of identifying which ones or how well they would score against our list".

The two other bases expressed similar sentiments as Base B in that there were projects within MAXIMO that would score relatively high on their lists; however, it is very difficult to identify those projects in a database as large as MAXIMO. Additionally, all three bases expressed concerns about having to manage project lists that included all

MAXIMO projects, therefore, they all kept smaller “to fund” lists to keep the list more manageable, “the tradeoff is sometimes we fund projects that are not the best projects, however, we do the best that we can” (Base A Project Manager, 2002).

There is no doubt that the linear model can be manipulated to justify a particular project(s). After all, it would be easy to give fours or fives to the highest weighted criterion for a project. However, at best this would do little more than bring up a single project or two into a higher-ranking slot to get them funded. The integrity of the entire list as a whole will still be intact and will continue to provide sound guidance for project execution. Furthermore, the linear model is not being audited by some outside entity where they are checking to see what projects are actually being funded and why. Therefore, if a command wants to fund a project that is low on the priority list; then fund that project. There is no reason to manipulate the data; it serves no purpose other than to show that you could cheat yourself.

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VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSION

This thesis clearly identifies the need for public works commands to use objective criteria to prioritize and fund Specific projects. The Navy cannot continue to fund projects based on subjective measures that most commands currently use today. As bases continue to age they will experience similar or worse facility catastrophes as outlined by Base A when three of their facilities roofs collapsed. The likely cause was the lack of attention and credence paid the AIS report.

Additionally, MAXIMO was developed for public works commands to manage and track their Specific projects along with other things. However, at all three commands I interviewed, I found that the public works staffs only use MAXIMO as a required input vehicle for data and not as a means to manage projects. On the contrary, every base uses a separate Excel spreadsheet to manage and fund their projects from. Their project lists are a smaller subset of the entire MAXIMO project database. However, as people move to other commands, projects are lost in the database void of MAXIMO. How many of MAXIMO's unknown projects are actually the project that will stop the roof from collapsing three years from now? What is the purpose of spending $250,000 on an AIS report every year if all it does is sit on the shelf like it does at too many bases today?

Every PWO should pull off the shelf their most current AIS report and carefully go over each facility to determine what facilities have critical line items and assess those line items to develop projects that immediately address critical deficiencies. Additionally, each base should develop objective criteria to be used in a linear model like the one provided here in this thesis as a baseline model for their command. It is too easy to say you are being objective in your project prioritization process; however, as we have seen in Table 5.5, this simply is not the case. Additionally, human beings will never be able to track and manage all the new and existing projects in MAXIMO without using some objective ranking process. However, if a ranking system is not used, we can be sure of overlooking hundreds of potential high impact Navy projects that will be forgotten or overlooked as they accumulate in MAXIMO. Constrained resources will

always exist in the Navy, therefore, we should be doing everything possible to make sure our resources are going to the projects that will give the Navy and base the biggest bang for the buck.

Furthermore, too much time and resources are being spent in management meetings where people discuss and compromise with each other on where their project ought to be placed in the "to fund" list. Additionally, undo influence is being placed on the PWO's from high ranking officials and base commanders during project ranking. How many times have we seen the Admiral or the base CO call the PWO with a pet project they had and it is immediately placed on the "to fund" list? Base CO's know relatively little about their base's Specific projects compared with the bases PWO; or at least they should. They rely on the PWO to give them sound advice and to tell them when their project is not a good project to fund. But they deserve the data to back up that claim, which is something that we currently cannot provide to the CO. Therefore, since no real measurable way is used to justify our current project order with any real objective criteria, we smartly succumb to the pressure of the high-ranking officials with their pet project. Who are we benefiting then? Not the base CO, after all, we are there to provide them with valuable facility advice, but we cannot offer any if we continue to rely on subjective and immeasurable project rankings criteria. The CO deserves better, the Navy deserves better, the taxpayers deserve better, and we deserve better.

This linear model was developed to precisely do just that. It provides the means and gives the ability to public works officers to use resources that will have the biggest impact for the Navy to perform its mission.

When the next PWO steps in our place, the outgoing PWO will be able to pass on to them the most current an up to date project list along with the justification of why each project is where is it in respect the entire list. PWO's will no longer need to spend long hours developing the Specific project turnover list for our replacement and come up with extravagant justifications and reasoning why a particular project is placed so high on the project list; when in actuality, it is the CO pet project and we had no means to recommend against it.

We are the Navy's designated people for that job, we can do better.

B. RECOMMENDATIONS

1. A measure to determine what percentage of AIS Specific projects are being funded compared with all Specific projects.
2. Determine how command criteria should be established and identify how to apply the weighting to each criterion in an objective means.
3. What is the feasibility and cost of using a NAVFAC wide computer system, which actively recommend projects to the users based on AIS information?
4. Developing a model and process that would update the AIS database in real time when work is executed on a facility that corrects AIS line item deficiencies that includes routine service calls.
5. Determine the cost, scope and feasibility of incorporating a linear model into MAXIMO for NAVFAC to give to all public works commands.

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APPENDIX A. LINEAR MODEL

	A	B	C	D	E	F	G	H	I	H	K
1	SAFT = Safety			**Cost VLOOKUP Table**			**Investment Category VLookUp Table**				
2	MISS = Mission			$1	10		Administration Facilities			1	1.000
3	CAIS = Critical AIS / DEIS / Code			$10,000	9		Ammo Supply and Storage Facilities			2	1.025
4	QOSV = Quality of Service			$25,000	8		Aviaation Maintenance Production Facilitie			3	1.025
5	FTRD = Footprint Reducion			$50,000	7		Aviation Operational Facilities			4	1.050
6	URRN = Urban Renewal			$100,000	6		Communication Operational Facilities			5	1.000
7	LCCS = Life Cycle Cost Savings			$150,000	5		Medical Facilities			6	1.025
8	COPR = CO Priority			$200,000	4		Other Maintenance Production Facilities			7	1.000
9	AISP = AIS Project			$250,000	3		Other Operational Facilities			8	1.000
10	PRCT = Project Cost			$400,000	2		Other Personnel Support Facilities			9	1.025
11	INVC = Investment Category			$2,000,000	1		Other Supply and Storage			10	1.000
12	PRSC = Project Score						POL Supply and Storage Facilities			11	1.025
13	COUG = Code Upgrade						RDT&E Facilities			12	1.000
14							Real Estate and Ground Structures			13	1.000
15							Shipyard Maintenance Production Facilitie			14	1.025
16							Training Facilities			15	1.050
17							Troop Housing and Messing Facilities			16	1.050
18							Utilities			17	1.050
19											
20											

21	A	B	C	D	E	F	G	H	I	H	K		L	M	N	O	P	Q	R
22		Base Weighting	17%	16%	14%	13%	10%	8%	7%	5%	4%		3%	3%		100%			Equity
23	#	Project Description	SAFT	MISS	CAIS	QOSV	LCCS	URRN	CORP	FTRD	AISP		PRCT	COUG	CumTotal	INVC	PRSC	T/F	Score
24	42	Boiler Plant Repairs (const)	4	4	5	3	4	1	3	1	1		$300,000	4	$300,000	1	3.40	1	176.28
25	19	ADA Ramp to Club Floor	5	5	2	5	1	1	1	1	1		$50,000	5	$350,000	1	3.28	1	32.14
26	18	Support: Asbestos Abatement, supplies	5	4	2	3	3	1	4	1	1		$90,000	5	$440,000	1	3.27	1	54.01
27	35	HH Admin Space Heating	2	4	5	3	4	1	4	1	3		$200,000	5	$640,000	1	3.27	1	116.48
28	13	Replace Number 2 Steam Boiler 823	4	5	4	3	2	1	1	1	1		$23,650	2	$663,650	1	3.20	1	14.83
29	30	Repair roof of Depository(Des/Build)	3	4	4	4	4	1	2	1	1		$120,000	1	$783,650	1	3.15	1	69.03
30	1	Fire Alarm NEX/NFCU (const)	5	3	5	1	1	1	3	1	1		$25,000	5	$808,650	1	3.03	1	14.85
31	16	Repair Steam System 344	3	5	3	4	2	1	2	1	1		$40,000	1	$848,650	1	3.03	1	23.76
32	40	Fire Alarm Upgrades Basewide (Phase 1)	5	2	4	2	4	1	3	1	3		$275,000	3	$1,123,650	1	3.03	1	145.46
33	39	Repair/Replace Exterior Stairs (const Phase 1)	5	3	4	2	2	3	2	1	1		$300,000	3	$1,423,650	1	3.00	1	155.54
34	31	Sidewalks/Lighting Various Locations	3	3	3	3	3	3	3	1	1		$100,000	3	$1,523,650	1	2.91	1	53.41
35	2	Renovate ITT workspaces/ ASF/Chaplin	1	3	4	4	2	3	5	1	1		$40,000	2	$1,563,650	1	2.91	1	22.81
36	33	Repair Ceiling Plumbing 344	3	3	4	3	4	1	3	1	1		$150,000	1	$1,713,650	1	2.90	1	78.65
37	29	Replace Chiller #1 330	1	4	5	4	4	1	1	1	1		$100,250	1	$1,813,900	1	2.88	1	52.99
38	38	Bathroom Upgrade Basewide	2	3	5	3	3	1	2	1	3		$250,000	4	$2,063,900	1	2.81	0	0.00
39	28	Repair Sidewalk at Ingrid	4	3	2	3	2	3	2	1	1		$50,000	1	$2,113,900	1	2.74	1	26.85
40	43	Gas Line Repair Lab-Rec	4	4	3	3	2	1	1	1	1		$275,000	2	$2,388,900	1	2.72	0	0.00
41	14	Directed Energy Lab	1	5	1	5	2	1	4	1	1		$29,000	2	$2,417,900	1	2.71	0	0.00
42	26	Replace Roof 826	1	4	4	3	4	1	2	1	1		$50,000	1	$2,467,900	1	2.71	1	26.56
43	34	Irrigation Upgrades Basewide	1	3	3	3	4	5	2	1	1		$150,000	2	$2,617,900	1	2.70	0	0.00
44	37	Fighter Lab	1	5	2	4	3	1	4	1	1		$289,000	2	$2,906,900	1	2.67	0	0.00
45	22	Relocate Heating System 345	5	2	2	3	3	1	1	1	1		$50,000	2	$2,956,900	1	2.65	0	0.00
46	24	Re-roof Bishop Hall	1	4	4	2	4	1	2	1	1		$60,000	2	$3,016,900	1	2.61	0	0.00
47	15	Repair Sewer Lift 425	1	4	5	3	2	1	1	1	1		$45,000	1	$3,061,900	1	2.61	0	0.00
48	3	Bishop Wing Entry, Terra Floors	2	2	3	2	2	4	4	1	1		$6,500	1	$3,068,400	1	2.56	0	0.00
49	32	Asphalt Repairs FY03	3	2	3	3	3	3	1	1	1		$100,000	1	$3,168,400	1	2.55	0	0.00
50	11	Repair Foot bridge between b-559 and b-540	5	2	2	1	1	3	2	1	1		$10,000	4	$3,178,400	1	2.54	1	5.08
51	12	Cell Phone Booster	1	4	4	4	1	1	1	1	1		$10,000	1	$3,188,400	1	2.53	0	0.00
52	25	Re-Roof Chapel/Multi Purpose Ctr	1	3	3	2	4	3	2	1	1		$90,000	2	$3,278,400	1	2.47	0	0.00
53	7	Provide A/C for Ingrid Rooms	1	2	2	5	1	1	5	1	1		$160,000	5	$3,438,400	1	2.34	0	0.00
54	9	Repair Storm Drain System 343	3	2	4	1	1	1	2	1	3		$20,000	1	$3,458,400	1	2.31	0	0.00
55	21	Repair Structural Cracks 343	3	2	2	2	1	1	3	1	1		$50,000	1	$3,508,400	1	2.09	0	0.00
56	8	Carpet, FY03 (do we want one job or many	2	1	2	3	1	1	2	1	4		$50	1	$3,508,450	1	2.03	1	2.03
57	27	Paint Exterior 357	1	2	2	2	2	4	2	1	1		$60,000	1	$3,568,450	1	2.02	0	0.00
58	10	Finish Club Floor	2	1	2	3	1	1	2	1	4		$22,000	1	$3,590,450	1	2.00	0	0.00
59	41	Paint Exterior 825, 826	1	2	2	2	3	4	2	1	1		$300,000	1	$3,890,450	1	2.00	0	0.00
60	4	Trail Repairs	3	1	1	1	1	4	3	1	1		$145,000	1	$4,035,450	1	1.87	0	0.00
61	36	Paint/Window Shades/Doors 368 and	1	2	2	2	2	3	2	1	1		$200,000	1	$4,235,450	1	1.85	0	0.00
62	17	Repair and Clean Scuppers 343/344/345	2	2	3	1	1	1	1	1	2		$50,000	1	$4,285,450	1	1.83	0	0.00
63	23	Drop Ceiling	1	2	2	2	1	1	3	1	3		$50,000	1	$4,335,450	1	1.83	0	0.00
64	20	Metering Housing	1	3	1	1	2	1	1	1	1		$50,000	1	$4,385,450	1	1.60	0	0.00
65												SumProject Cost	$4,385,450						1070.76
66												Funds Available	$1,925,000						Constraint Parameter
67												Funds Used	$1,923,950						
68																			
69																			
70																			
71																			
72																			
73																			
74																			

ELEC =	Electrical
MECH =	Mechanical
STRU =	Strucural
ROOF =	Roofing
PAIN =	Painting
PAVI =	Paving
PIER =	Piers/Wharfs
RENO =	Renovation
URRN =	Urban Renewal
FTRD =	Footprint Reduction
SEAB =	Seabee

21	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF
22					Project Type									
23	ELEC	MECH	STRU	ROOF	PAIN	PAVI	PIER	RENO	URRN	FTRD	SEAB			
24		1												
25								1						
26								1						
27	1	1												
28		1												
29				1										
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62				1										
63								1						
64	1													
65	3	8	1	4	0	2	0	3	4	0	3			
66	1	0	0	0	0	0	0	0	0	0	0			
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APPENDIX B. EXCEL INSTRUCTION

A. PROGRAMMING THE EXCEL SPREADSHEET

In the cells of the linear model, cell rows 1 through 20 are assigned either as informational cells to help the user with the abbreviations used in model or are assigned as VLOOKUP tables for the model. For VLOOKUP table information and uses, refer to the Microsoft Excel 2000 Bible, (Walkenbach, 1999) or most any other Excel reference manual.

Three VLOOKUP tables are used in this linear model. The first VLOOKUP table located in cells D1:E11 provides the ranking score for the project cost; project costs are input into column L by the users. For example, if a project costs $55,000, the VLOOKUP table will return a score of (7); see Table 4.3. The second VLOOKUP table located in cells G1:K19 returns the Investment Category bonus, which depends on the Investment Category Code of the project. For Example, if the project's Investment Category is 15 (Training Facilities), the linear model will return a bonus score of five percent; see Table 4.2.

The final VLOOKUP table is located on a separate worksheet called "ETABLE" which is located within the "Thesis Project Linear Model" Excel workbook. The "ETABLE" VLOOKUP is not included in this thesis' appendix due to its size. It contains 11450 rows of data, which separates project cost into $50 increments. The "ETABLE" VLOOKUP converts the project cost into a ratio score. The ratio score is the ratio of the projects cost to the lowest possible project cost within the "ETABLE" data. The Equity Score (found in Column R) is the product of the Project Score (found in column P) and the ratio score.

As an example, suppose you have four potential projects that need to be funded, shown in Table A2-1. The command only has $200,000 to spend and therefore will not be able to fund all four projects. The model should recommend funding project 1 since project 1 has the highest Project Score. However, if the model maximizes the sum of the Project Scores instead of the Equity Score, the model will recommend funding projects 2,

3, and 4 even though project 1 scored the highest overall. This is because the sum of the Project Scores 2, 3, and 4 are greater than the Project Score of project 1. However, the "ETABLE" VLOOKUP corrects this problem by taking the Project Score and multiplying it with the ratio score (Project cost / lowest cost).

Project Number	Project Score	Cost	ETABLE Ratio	Equity Score
1	3.8	$200,000	6.7	25.3
2	2.4	$50,000	1.7	4.0
3	1.9	$30,000	1.0	1.9
4	2.6	$75,000	2.5	6.5

Table A2-1. ETABLE Ratio Equity Score.

The "ETABLE" ratio score between project 2 and 3 is 1.7 ($50,000 divided by $30,000 rounded). The "ETABLE" ratio score is then multiplied by the project score, which is 2.4 for project 2. The Equity Score for project 2 equals 2.4 x 1.7 = 4.0.

By maximizing the Equity Score against the funding constraint of $200,000 instead of the Project Score, the Excel linear model recommends project 1 for funding since the Equity Score in project 1 is greater than the sum of the Equity Scores of Projects 2, 3 and 4.

B. LINEAR PROGRAM DEFINITIONS

1. Variables

X_i = projects considered for funding
$i = 1$ to n; where n = total number of projects.

R_{ij} = user defined rank score for each project under each criteria.
$i = 1$ to n; where n = total number of projects.
$j = 1$ to m; where m = total number of criteria

W_j = weighting for each criteria
$j = 1$ to m; where m = total number of criteria

C_i = cost of project i
$i = 1$ to n; where n = total number of projects

E_i = Equity Score
$i = 1$ to n; where n = total number of projects

P_{ti} = Project Type for each project considered

t = 1 to q; where q = total number of Project Types assigned to each project X_i

i = 1 to n; where n = total number of projects

T = Minimum Project Type execution level defined by the user as a constraint. $0 \leq T \leq P_{ti}$

F = Funds available to the command for project execution

B_c = Bonus percent given for Investment Category.

c = {0, 0.025, 0.05} corresponding to {low, medium, high} IC.

2. Variable Examples

$X_{i=1}$ = Fire Alarm NEX/NFCU
$X_{i=2}$ = Renovate ITT workspaces/ASF/chaplain
. .
. .
. .
$X_{i=43}$ = Gas-line repair lab-rec;

$C_{i=1}$ = \$25,000
$C_{i=2}$ = \$40,000
. .
. .
. .
$C_{i=43}$ = \$275,000;

$W_{j=1}$ = Safety (17%)
$W_{j=2}$ = Mission (16%)
. .
. .
. .
$W_{j=11}$ = Code Upgrade (3%);

$R_{ij=1,1} = 1$
$R_{ij=1,2} = 3$
. .
. .
. .
$R_{ij=43,11} = 2$;

$E_{i=1} = 14.85$
$E_{i=2} = 22.81$

$$\vdots \qquad \vdots$$

$E_{i=43} = 0.00$

3. Objective Function

$$\max \sum_{i=1}^{n} E_i * W_j * Bc * R_{ij} * X_i$$

4. Constraints

X_i = Binary

R_{ij} = Integer; $1 \leq R_{ij} \leq 5$

$0 \leq W_j \leq 1; \sum W_j = 1$

$E_i = C_i / \min\{C_1, C_2, C_3, \ldots, C_n\}$

$$\sum_{t=1}^{g} P_{ti} \geq T_t$$

$$\sum_{i=1}^{n} C_i * X_i \leq F$$

$F \geq 0$

$T_t \geq 0$

$C_i \geq \$50.00$

$P_{ti} \geq 0$

$B_c = \{ 0 – Low; 0.025 – Medium; 0.05 – High\}$

C. EXCEL CELL DEFINITIONS

Cell row 22 columns C through M and O are used for criteria percentages that were established by Base B; found in Table 4.1. Cell rows 24 and down are reserved for project input. Columns C through M are reserved for the commands to rank score each criterion on a scale of 1 to 5.

A rank score of: 5 = Extremely High
4 = Above average
3 = Average
2 = Below Average
1 = Not at all or very low

is placed in each cell column below the criteria depending on how well the individual project in that row addresses the columns criteria. Column O is used to insert the Investment Category for the project. Column N displays the running total of all project costs. Column N shows the total Specific project backlog.

Column P (Project Score) uses the "sum products" function in Excel to multiply the criteria percentage array, row 22, with the rank score array (rows 24 down) for each project. The actual formula used in column P for this linear model is shown in Formula A2.1. The "sum product" formula returns a Project Score of 3.4 for the first project found in row 24 in Appendix A.

```
(SUMPRODUCT($C$22:$K$22,C24:K24)+$L$22*VLOOKUP(L24,$D$2:$E$11,2)+($M$22*M24))*VLOOKUP(O24,$J$2:$K$19,2)
```

Formula A2.1. Project Score.

Formula A2.2 shows how the Equity Score is calculated. It is found in column R beginning in row 24. The Equity Score in row 24 returns the actual value of 253.04.

```
P24*Q24*VLOOKUP(L24,ETABLE!$A$1:$B$11450,2)
```

Formula A2-2. Equity Score.

Column Q (Changing Cells), beginning in row 24, is formatted as binary cells to return values of 1 or 0, true or false. If the linear model returns a value of 1 (true), the linear model is saying that the project in that row should be funded. If the value of 0 (false) is returned, then that project should not be funded. If the constraint parameters, found in cells S66:AC66, change or the available funds change for the command, found in L66, the linear models binary true or false values will change accordingly.

Columns S through AC beginning on row 24 are used to input the project type; see Table 4.4. Each Specific project can have one or more project types assigned to that project. Note: each project can be assigned to as many project types that are applicable. For instance, a major renovation to a building may include electrical, mechanical, structural, renovation, roofing, painting and Seabees. However, if the projects types are assigned too liberally, this may reduce the effectiveness of setting constraint parameters.

For example, if the intent is to fund at least three major exterior painting projects per year, the command should not assign painting as a project type to other projects such as renovations. Otherwise, when the linear model is executed, it may have three painting projects already assigned to projects and therefore will not recommend funding the true exterior painting projects.

Cells S65:AC65 sum the product of the linear models binary cells found in column Q with the project types. If the constraint parameter for project type "Roofing" is three, the model will continue to iterate until it return at least three roofing projects to the true condition. Formula 4.3 located in Cell S65 is provided below as reference. This formula is copied across S65:AC65.

SUMPRODUCT($Q$24:$Q$64,S24:S64)

Formula A2-3. Constraint Parameters.

Cell L65 displays the sum of the Specific project backlog. In Cell L66, the command inputs the resource funding level. For instance, cell L65 shows a backlog of $4,385,443, however, the command only has $1,925,000 (Cell L66) to fund the requirements. Cell L67 is calculated by the linear model using the Solver function. The linear model maximizes the sum of the "Equity Score" column found in cell R65 which is calculated using a computer iteration process taken from the resource constraint level (Cell L66) and project constraints (S66:AC66).

D. RUNNING SOLVER IN EXCEL

The Solver function is found in the Tools menu in Microsoft Excel. If the Solver function is not present, it will need to be added into Excel by going to Add-Ins under the Tools menu. Scroll down and click on Solver Add-Ins. Solver should now be installed in your computer.

When the Solver function opens, the first box is "Set Target Cell". In this linear model, the Target Cell is R65 (sum of the Equity Scores). The next box shows "Maximize, Minimize or Value of". Make sure the Maximize button is checked since we are trying to maximize the sum of the "Equity Score". The "Changing Cells" are

Q24:Q64. These are true / false binary cells the linear model sets during the iteration process when maximizing the "ETABLE" scores. The computer will maximize the total "Equity Score" by setting true or false each cell during the computer iteration process.

In the "Subject to the Constraint" box, cell C67 is set less than cell C66 (C67 <= C66). This sets the linear models funds used (C67) less than or equal to the total funds available (C66). The model should not provide a solution greater the total funds available to the public works command. Set cells Q24:Q64 as binary. Finally S65:AC65 is set greater than S66:AC66, (S65:AC65 >= S66:AC66). This makes sure that the sum of each Project Type (S65:AC65) is always greater than or equal to the set constraint (S66:AC66).

Under the options button, Solver is set to "Assume Linear Model" and "Assume Non-Negative".

After everything has been set, press "Solve". The linear model will take a few seconds while the iteration process takes place. Once the process is complete, column Q will have either a 1 or a 0 assigned to each project, which shows which projects the linear model selected as true to fund according to the constraints set by the command.

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